LIME

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Lime is an important chemical with numerous chemical, industrial, and environmental uses in the United States. Some evidence of its use as a lime mortar has been found at a site in what is now eastern Turkey that dates from 7,000 to 14,000 years ago. More definite evidence of its use in mortars in the Near East and in the former Yugoslavia dates from 8,000 years ago. In Tibet, it was used to stabilize clays in the construction of the pyramids of Shersi, which were built 5,000 years ago. The ancient Egyptians used lime as an ingredient in mortar and plaster. The Chinese, Greek, Roman, and other ancient civilizations used lime for construction, agriculture, bleaching, and tanning (Oates, 1998a, p. 3-4). Its uses began expanding with the advent of the industrial revolution, but it remained primarily a construction commodity until the rapid growth of the chemical process industries at the beginning of the 20th century. At the turn of the 20th century, more than 80% of the lime consumed in the United States went for construction uses, but currently more than 90% is being consumed for chemical and industrial uses.

The term "lime" as used throughout this chapter refers primarily to six chemicals produced by the calcination of high-purity calcitic or dolomitic limestone followed by hydration where necessary. They are (1) quicklime, calcium oxide (CaO); (2) hydrated lime, calcium hydroxide [$Ca(OH)_2$]; (3) dolomitic quicklime ($CaO \cdot MgO$); two types of dolomitic hydrate, (4) type N [$Ca(OH)_2 \cdot MgO$] and (5) type S [$Ca(OH)_2 \cdot Mg(OH)_2$]; and (6) dead-burned dolomite. Nondolomitic quicklime and hydrated lime are also called high-calcium lime. Lime also can be produced from a variety of calcareous materials, such as aragonite, chalk, coral, marble, and shell. Lime is also regenerated; that is, produced as a byproduct, by paper mills, carbide plants, and water-treatment plants. Regenerated lime, however, is beyond the scope of this report.

Production

Lime is a basic chemical that was produced as quicklime in 32 States and Puerto Rico (table 2). Hydrated lime was produced in four additional States in which hydrating plants used quicklime shipped in from out of State. Principal producing States were, in descending order of production, Missouri, Kentucky, Alabama, Ohio, Texas, and Pennsylvania.

Domestic production data for lime are derived by the U.S. Geological Survey (USGS) from two separate, voluntary surveys of U.S. operations. The survey used to prepare this report is the annual "Lime" survey. Quantity data are collected for 28 specific and general end uses, and value data are collected by type of lime, such as high calcium or dolomitic. Because value data are not collected by end use, value data shown in table 4 are determined by calculating the average value per metric ton of quicklime sold or used for each respondent and then multiplying it by the quantity of quicklime the respondent reported sold or used for each end use. The same calculation is performed for hydrated lime sold or used. Table 4 displays the total quantity sold or used for an end use and the total value of the quicklime and hydrate sold or used for that end use calculated as described above.

The USGS maintains a list of operations classified as producing or idle; in 1998, there were 115 operations listed. Four of these operations are not surveyed at the producers' request, and estimates are made by using reported prior-year production figures or other industry data. Three of these operations were idle in 1998. Of the 108 operations to which the 1998 annual survey request was sent, 103 responded, representing 94% of the total sold or used by producers. Production for five nonrespondents was estimated by using reported prior-year production figures.

Total lime sold or used by domestic producers in 1998 increased by about 454,000 metric tons (500,000 short tons) to 20.1 million tons (22.2 million short tons) compared with that of 1997 (table 1). Production included the commercial sale or captive consumption of quicklime, hydrated lime, and dead-burned refractory dolomite. These products were valued at $1.22 billion. Commercial sales increased by 556,000 tons (613,000 short tons) to a record high of 17.8 million tons (nearly 19.6 million short tons), and captive consumption decreased by 102,000 tons (112,000 short tons) from the revised 1997 figures to about 2.29 million tons (2.53 million short tons). Data in table 1 now include production from Puerto Rico, as do the revised figures for 1996 and 1997. This facilitates comparison of data in the various tables.

The lime industry went through some major changes in company ownership in 1998. Carmeuse Lime, Inc., which had acquired Marblehead Lime Co. in 1994 and the Pennsylvania lime operations of Tarmac America, Inc. (formerly Wimpey Minerals PA, Inc.) in 1996, acquired Pittsburgh-based Dravo Corp. (Dravo Corp., 1998). Dravo was the second largest lime producer in the United States with lime plants in Alabama and Kentucky and a hydrating plant in Louisiana. Carmeuse also announced a planned joint-venture merger of its North American lime operations with those of Lafarge S.A. Lafarge owned lime plants in Ohio, Texas, and Canada that were acquired as part of Lafarge's takeover of Redland PLC. The joint-venture company will be owned 60% by Carmeuse and 40% by Lafarge (Industrial Minerals, 1998). Carmeuse and Lafarge finalized their agreements effective February 18, 1999

(Carmeuse North America, 1999). Refractories producer A.P. Green Industries, Inc. (parent of APG Lime Corp.), was acquired by Global Industrial Technologies, Inc. Global's purpose in making the acquisition was to merge the refractories operations of A.P. Green with those of its subsidiary Harbison-Walker Refractories Co. (Global Industrial Technologies, Inc., 1998). In a deal finalized on May 22, Oglebay Norton Co. acquired U.S. and Canadian lime and limestone producer Global Stone Corp. (Oglebay Norton Co., 1998). On June 9, 1998, Graymont Ltd. announced that it had acquired 100% of GenLime LP of Genoa, OH, and Bellefonte Lime Co. of Bellefonte, PA. These operations will become part of Graymont's East Division Operations, which includes Graybec Calc, Inc., and Graystone Materials, Inc. Graymont (parent of Continental Lime, Inc., and Continental Lime Ltd.) now operates 14 lime plants in Canada and the United States (National Lime Association, 1998). The small Lee Lime Corp. operation in Lee, MA, which became part of Medusa Minerals Co. in 1997, became part of Southdown, Inc., with the merger of cement producers Southdown and Medusa Corp. in 1998 (Drake, 1998).

With all the acquisition and merger activities, 1998 was a relatively quiet year for plant construction. Carmeuse Lime continued renovation and construction work on its dolomitic lime plant at Maple Grove, OH. The project involves the refurbishment of two straight rotary kilns with a combined capacity of 1,090 tons per day (1,200 short tons per day). The modernization project was expected to be completed in September 1999. Under a long-term contract with Dow Chemical Co., Carmeuse is committed to supply more than 181,000 tons per year (200,000 short tons per year) to Dow's Ludington, MI, magnesium hydroxide plant (National Lime Association, 1999). Mississippi Lime Co. started up its new 120,000-ton-per-year (132,000-short-ton-per-year) Maerz twin vertical shaft parallel flow regenerative kiln (Don Muller, Mississippi Lime Co., oral commun., 1999). Much of the construction work on the new Palmetto Lime LLC plant in Charleston, SC, was completed in 1998, and the plant took its first delivery of limestone in December, but startup of the plant was not expected until summer 1999 (Rick Werner, Palmetto Lime LLC, oral commun., 1999).

Of the 49 companies manufacturing lime at the end of 1998, 31 were primarily commercial producers, and 18 were predominantly captive producers. The 31 commercial producers operated 62 lime plants producing quicklime and 8 separate hydrating plants (including 1 lime plant that was idle but operated its hydrator). The 18 captive producers operated 42 plants producing quicklime primarily for internal company use. At year's end, the top 10 companies were, in descending order of production, (1) Carmeuse Lime, which consisted of Carmeuse Pennsylvania, Inc., Dravo Lime Co., and Marblehead Lime; (2) Chemical Lime Co.; (3) Mississippi Lime; (4) Continental Lime; (5) Global Stone; (6) APG Lime; (7) Martin Marietta Magnesia Specialties, Inc.; (8) Bellefonte Lime; (9) Lafarge Lime, Inc.; and (10) U.S. Lime and Minerals, Inc. These companies operated 40 lime plants and 6 separate hydrating plants and accounted for 80% of commercial sales of quicklime and hydrated lime combined and 73% of total lime production.

Domestic lime plant capacity is based on 365 days minus the average number of days for maintenance times the average 24-hour capacity of quicklime production, including quicklime converted to hydrated lime. In 1998, capacity data were incomplete, but on the basis of data from 38 plants, the U.S. lime industry operated at about 79% of capacity. The calculations do not include combined commercial and captive producers, hydrating plants, plants that commissioned new kilns during the year, and Puerto Rico. This is slightly lower than the operating rate of 81% calculated for 1997. Capacity utilization would be slightly lower if the capacity of several idle or mothballed plants were factored into the calculations.

Environment

Currently the most common fuel used in lime production is coal. Emissions generated in the combustion of coal and other fuels makes the lime industry subject to regulation under the Clean Air Act. Of concern to the lime industry are the costs and obligations expected for additional monitoring, reporting, and control of hazardous air pollutants such as mercury and particulate matter. Of longer term concern, but with potentially greater impacts, are the international discussions on the reduction of greenhouse gas emissions, particularly carbon dioxide. Lime production generates carbon dioxide from the combustion of fuels and from the calcination process, which dissociates calcium carbonate into calcium oxide and carbon dioxide. Any program to regulate carbon dioxide emissions would affect lime producers.

Consumption

The breakdown of consumption by major end uses (table 4) was as follows: 39% for metallurgical uses, 26% for environmental uses, 24% for chemical and industrial uses, 9% for construction uses, and 1% for refractory dolomite. Captive lime accounted for about 11% of consumption and was used mainly in the production of steel in basic oxygen furnaces, sugar refining, and magnesia production. Almost all data on captive lime consumption, excluding the sugar industry, were withheld to protect company proprietary information. As a result, table 4 simply lists the total quantity and value of lime by end use. End uses with captive consumption are listed in footnote 4 of the table.

In steel refining, quicklime is used as a flux to remove impurities, such as phosphorus, silica, and sulfur. Dolomitic lime is often substituted for a fraction of the high-calcium lime to extend refractory life. Dolomitic quicklime is also used as a flux in the manufacture of glass. The steel industry accounted for about 30% of all lime consumed in the United States. Lime consumption by the iron and steel industry was essentially unchanged at 6.08 million tons (6.70 million short tons) compared with that of 1997.

The lagging steel market was the result of a decrease in domestic steel production caused by a surge in low-valued steel imports beginning in the second quarter of 1998. In 1998, imports of steel mill products increased by 33%, to a record high of nearly 37.7 million tons (41.5 million short tons). Japan and Russia accounted for 60% of the increase. The surge in imports was the result of very low prices being offered by some foreign producers, which caused domestic prices to plummet and left U.S. steel companies with large inventories and, in a number of cases, severe financial losses (Trickett, 1999). The U.S. steel industry and the steelworkers' union registered complaints of foreign dumping of hot-rolled sheet against Brazil, Japan, and Russia. In November, the U.S. Department of Commerce (DOC) made a preliminary "critical circumstances" finding that could have resulted in duties being imposed on the material, including any arriving 90 days before the DOC published its preliminary antidumping margins (Kelly, 1998). Antidumping duties against Brazilian steel were avoided with an agreement between the Brazilian Government and the DOC that put a quota and a minimum price on hot-rolled steel bound for the United States (Kepp, 1999). On June 11, 1999, the U.S. International Trade Commission (ITC) voted unanimously in a final injury determination against hot-rolled imports from Japan. ITC's duty order will affect all imports entering the United States on or after February 12, 1999. The final antidumping margins were issued earlier by the DOC (Kelly, 1999a). Duties against Russian steel were avoided in an agreement, finalized on July 12, 1999, establishing import quotas and minimum prices on Russian hot-rolled steel. The agreement eliminates imports of most hot-rolled product for the remainder of 1999; beginning in 2000, annual imports will be allowed to increase gradually to 725,000 tons (800,000 short tons) by 2003, at which point imports will equal an 80% reduction from those of 1998. Imports of other types of steel from Russia were allowed to increase, but the total annual imports will be 2.2 million tons (2.4 million short tons), which is a significant decrease from the 4.78 million tons (5.27 million short tons) of steel mill products exported to the United States in 1998 (Kelly, 1999b). Antidumping complaints have also been filed or are being prepared against other types of steel.

The increased levels of steel imports were the result of complex factors in international markets. With the onset of the recession in Asia, exports of Russian steel formerly directed to countries in the Far East were redirected to the United States. Brazil and Japan, each with sagging economies and sinking currencies, tried to improve their situations by exporting product to the largest, strongest market in the world. Ironically, to meet increased demand from customers, some U.S. steel companies were importing steel from these countries. Adding to the problems is that new capacity has continued to come on-stream in the United States in recent years with more pending.

In nonferrous metallurgy, lime is used in the beneficiation of copper ores to neutralize the acidic effects of pyrite and other iron sulfides and to maintain the proper pH in the flotation process. It is used to process alumina and magnesia, to extract uranium from gold slimes, to recover nickel by precipitation, and to control the pH of the sodium cyanide solution used to leach gold and silver from the ore. Such leaching processes are called dump leaching when large pieces of ore are involved, heap leaching when small pieces of ore are involved, and carbon-in-pulp cyanidation when the ore is leached in agitated tanks. Dump and heap leaching involve crushing the ore, mixing it with lime for pH control and agglomeration, and stacking the ore in heaps for treatment with cyanide solution. Lime is used to maintain the pH of the cyanide solution at a level between 10 and 11 to maximize the recovery of precious metals and to prevent the creation of hydrogen cyanide.

The tailings that result from the recovery of precious metals may contain elevated levels of cyanides. Lime is used in treatment processes, such as, Cyanisorb, alkaline chlorination, and sulfur dioxide/air, to recover the cyanides.

In the environmental sector, lime is used in the softening and clarification of municipal potable water, and to neutralize acid mine and industrial discharges. In sewage treatment, lime's traditional role is to control pH in the sludge digester, which removes dissolved and suspended solids that contain phosphates and nitrogen compounds. It also aids clarification and in destroying harmful bacteria. More recently, the largest use in sewage treatment has been to stabilize the resulting sewage sludges. Sewage sludge stabilization, also called biosolids stabilization, reduces odors, pathogens, and putrescibility of the solids. In lime stabilization, the basic process involves mixing quicklime with the sludge to raise the temperature and pH of the sludge to minimum levels for a specified period of time. Lime consumption for all sludge treatment increased by 17%. The sewage sludge market actually decreased by 3%, but the industrial and hazardous waste market increased by an impressive 85%.

In flue gas desulfurization (FGD) systems serving electric utility and industrial plants and incinerators, lime is used to react with sulfur oxides in the flue gas and is used to stabilize the resulting sludge before disposal. In 1998, the FGD market bounced back from the slight decrease in 1997 that was caused by mild seasonal temperatures. Bolstered by a 14% increase in sales to utility powerplants, the market topped 3 million tons for the first time with a total of 3.11 million tons.

Lime is used by the pulp and paper industry in the basic Kraft pulping process, where wood chips and an aqueous solution (called liquor) of sodium hydroxide and sodium sulfide are heated in a digester. The cooked wood chips (pulp) are discharged under pressure along with the spent liquor. The pulp is screened, washed, and sent directly to the paper machine or for bleaching. Lime is sometimes used to produce calcium hypochlorite bleach for bleaching the paper pulp. The spent liquor is processed through a recovery furnace where dissolved organics are burned to recover waste heat and where sodium sulfide and sodium carbonate are recovered. The recovered sodium sulfide and sodium carbonate are diluted with water and then treated with slaked lime to recausticize the sodium carbonate into sodium hydroxide (caustic soda) for reuse. The paper industry also uses lime as a coagulant aid in the clarification of plant process water. In 1998, lime consumption for pulp and paper production, excluding precipitated calcium carbonate production, decreased by 14%. The pulp and paper industry experienced increased imports and high inventory levels, which resulted in decreased pulp production. At the same time, the industry continued making capital improvements to recycle as much calcium carbonate sludge as possible for economic and environmental reasons.

Lime is used, generally in conjunction with soda ash, for softening plant process water. This precipitation process removes bivalent soluble calcium and magnesium cations (and, to a lesser extent, ferrous iron, manganese, strontium, and zinc), which contribute to the hardness of water. This process also reduces carbonate alkalinity and dissolved solids content.

Lime is used to make precipitated calcium carbonate (PCC), a specialty filler used in premium-quality coated and uncoated papers, paint, and plastics. The most common PCC production process used in the United States is the carbonation process. Carbon dioxide is bubbled through milk-of-lime, a suspension of hydrated lime in water, to form a precipitate of calcium carbonate and water. The reaction conditions determine the size and shape of the resulting PCC crystals. Lime demand for PCC production increased by 14%, continuing the strong growth exhibited by this market in the 1990's.

The chemical industry uses lime in the manufacture of alkalies. Quicklime is combined with coke to produce calcium carbide, which is used to make acetylene and calcium cyanide. Lime is used to make calcium hypochlorite, citric acid, petrochemicals, and other chemicals.

In sugar refining, milk-of-lime is used to raise the pH of the product stream, precipitating colloidal impurities. The lime itself is then removed by reaction with carbon dioxide to precipitate calcium carbonate. The carbon dioxide is obtained as a byproduct of lime production.

In construction, hydrated lime and quicklime are used in subgrade stabilization to stabilize fine-grained soils in place (subgrade) or borrow materials that are employed as subbases, such as hydraulic clay fills or otherwise poor-quality clay and silty materials obtained from cuts or borrow pits. Lime is also used in base stabilization, which includes upgrading the strength and consistency properties of aggregates that may be judged unusable or marginal without stabilization. Common applications for lime stabilization included the construction of roads, airfields, building foundations, earthen dams, and parking areas.

Traditionally, most of the lime purchased for stabilization is bought to build and maintain State and Federal roads. Funding for these purchases depends on the level of State and Federal road-building appropriations. Although lime has been routinely used for soil stabilization in the United States for decades, its acceptance and usage varies from State to State. In recent years, its reputation has spread, which has resulted in increased usage for road construction in States that previously had only a limited market, and in expanded private sector sales for use in stabilizing soils at construction sites, such as subdivisions and industrial parks. The strong U.S. economy, good construction weather, and ample State and Federal funding contributed to the strength of this market in 1998. Sales for soil stabilization increased by 13% compared with those of 1997.

In road paving, hydrated lime is used in hot mix asphalt to act as an antistripping agent. Stripping is generally defined as a loss of adhesion between the aggregate surface and asphalt cement binder in the presence of moisture. Lime is also used in cold in-place recycling for the rehabilitation of distressed asphalt pavements. Existing asphalt pavement is pulverized by using a milling machine, and a hot lime slurry is added along with asphalt emulsion. The cold recycled mix is placed and compacted by using conventional paving equipment, which produces a smooth base course for the new asphalt surface. In 1998, sales for use in asphalt increased by nearly 35%.

In the traditional building sector, quicklime is used to make calcium silicate building products, such as sand-lime brick and autoclaved aerated concrete (AAC). AAC offers the advantage of producing building materials that can be cut, drilled, and nailed like wood, but with the advantages of a concrete product. Hydrated lime is used in plaster, stucco, and mortars to improve durability.

Dead-burned dolomite, also called refractory lime, is used as a component in tar-bonded refractory brick used in basic oxygen furnaces. Hydrated lime is used to produce silica refractory brick used to line industrial furnaces.

Prices

The average values per ton of lime rounded to three significant figures are discussed in dollars per metric ton with accompanying conversions into dollars per short ton. For accuracy, the conversions were made from the unrounded metric value and, as a result, may not be an exact conversion of the rounded values. All value data for lime are reported by type of lime produced—high-calcium quicklime, high-calcium hydrate, dolomitic quicklime, dolomitic hydrate, and dead-burned dolomite. Emphasis is placed on the average value per ton of lime sold.

In 1998, prices were essentially unchanged from those of 1997, with the few exceptions mentioned below. The average unit value per ton of all lime sold or used by producers, on an f.o.b. plant basis, was $60.50 ($54.90 per short ton). The average values per ton of lime sold and used, by type of lime, were $57.60 ($52.30 per short ton) for quicklime, $78.90 ($71.60 per short ton) for hydrated lime, and $87.80 ($79.60 per short ton) for refractory dolomite.

The average value per ton of quicklime sold was $57.00 ($51.70 per short ton). The average value per ton of high-calcium quicklime sold was $56.90 ($51.70 per short ton). The average value per ton of dolomitic quicklime sold increased by nearly $1.00 to $57.30 ($52.00 per short ton). The average value per ton of refractory dead-burned dolomite sold was $87.30 ($79.20 per short ton).

The average value per ton of hydrated lime sold decreased slightly to $79.60 ($72.30 per short ton). The average value per ton of high-calcium hydrate sold was $75.40 ($68.40 per short ton). The average value per ton of dolomitic hydrate sold decreased by about $4.00 to $100.70 ($91.40 per short ton). The high dolomitic hydrate value is characteristic of high-value specialty products, such as mason's lime, which is more expensive to manufacture (requires pressure hydration) and is frequently shipped in bags.

Foreign Trade

The United States imported and exported quicklime, hydrated lime (slaked lime), hydraulic lime, and calcined dolomite (dolomitic lime). Combined imports of lime (table 6) were 231,000 tons (255,000 short tons) at a total value of $22.7 million, with 88% coming from Canada, 7% coming from Mexico, and 4% from China. Combined exports of lime (table 7) were 56,200 tons (61,900 short tons) at a total value of $9.11 million, with 63% going to Canada, 22% going to Mexico, 10% going to other Western Hemisphere nations, and most of the remaining 5% going to Asia.

No tariffs are placed on imports of hydraulic lime, quicklime, and slaked lime from countries with normal trade relations (NTR) with the United States. The 3.6% ad valorem (percentage of value) tariff on imports of calcined dolomite from NTR countries was reduced to 3.0% effective January 1, 1999. This tariff is scheduled for another reduction effective December 31, 1999 (U.S. International Trade Commission, January 22, 1999, 1999 U.S. tariff and trade data for a specific product, accessed July 13, 1999, at URL http://205.197.120.17/scripts/tariff/asp).

World Review

With the exception of industrialized nations with good data collection, accurate lime data for many countries are frequently difficult to acquire. The variations in quality, types of lime, production technologies, and industries manufacturing lime and the frequent confusion with limestone data make accurate reporting of world lime data (table 8) extremely difficult and certainly incomplete. The following is a brief discussion of acquisitions or new construction in specific countries.

Estonia.—Partek Nordkalk AB of Finland acquired Rakke Lubjatehase AS, Estonia's leading producer of quicklime. Partek Nordkalk acquired 40% of Rakke Lubjatehase in 1997 and began an investment program to modernize the plant, which increased capacity and improved product quality. Rakke Lubjatehase produced quicklime and ground limestone for markets in Estonia, Latvia, Lithuania, and Russia. The acquisition of the remaining 60% of Rakke Lubjatehase strengthened Partek's presence in the eastern Baltic Sea region and provided ready access to the markets in St. Petersburg, Russia (Partek Corp., August 14, 1998, press release, accessed June 14, 1999, at URL http://www.partek.fi/).

***Finland.*—**In December, Partek Nordkalk announced the startup of the new kiln at its Tytyri lime plant at Lohja. The new kiln has a capacity of 140,000 tons per year (154,000 short tons per year) and will boost the overall plant capacity to 215,000 tons per year (Partek Corp., December 21, 1998, press release, accessed June 14, 1999, at URL http://www.partek.fi/).

***Italy.*—**In 1998, the Italian lime industry had 30 major lime plants operated by 24 companies and approximately 200 very small regional producers serving local aglime and building markets. Unicalce S.p.A., part of the Nicci Donadoni Group conglomerate, was the largest lime producer in Italy. Other significant producers were Fassa Uno S.p.A., Fornaci Grigolin S.p.A., Fornaci De Sala Albnarro, and Fornaci Crovato S.p.A. (Gypsum, Lime & Building Products, 1998). In 1998, Fornaci Calce Grigolin S.p.A, located in northwestern Italy near Ponte Della Priula, started operation of its new 300-ton-per-day (330-short-ton-per-day) Maerz Ofenbau AG vertical shaft kiln (World Cement, 1998b). Villaga Calce S.p.A. ordered a 100-ton-per-day (110-short-ton-per-day) Maerz-RCE vertical shaft kiln for its Ceraino plant in northern Italy. The natural-gas-fired kiln was due to go into operation in mid-1999 (World Cement, 1998a).

***Jamaica.*—**In December, the Rugby Group PLC announced that it had entered into a joint-venture agreement with Clarendon Lime Company Ltd. to build a 130,000-ton-per-year lime kiln on a greenfield site in Clarendon, Jamaica. The project will cost $25 million, and Rugby will hold 61% of the new company called Rugby Jamaica Lime and Minerals Ltd. Construction was scheduled to begin in early 1999, with completion scheduled for the second quarter of 2000. Long-term supply agreements will ensure that this joint venture will be the principal lime supplier to alumina producer Jamalco, a Jamaican company 50% owned by the Jamaican Government and 50% by Alcoa Inc. (Rugby Group PLC, December 9, 1998, press release, accessed January 11, 1999, at URL http://www.rugbygroup.co.uk/cgi-bi...=index.html&footer=newsfooter.html).

Current Research and Technology

Although lime calcination technologies are well-established and advancements tend to be improvements of well established designs, a few notable developments have been made. Fluidized bed kilns have been installed for the calcination of friable or sandy limestones of less than 2 millimeters (0.0787 inch). The flash calciner process has been used for high-capacity kilns calcining finely divided limestones of less than 1 millimeter (0.0394 inch). Other designs are the top-shaped (or Chisaki) and the traveling grate kilns, both low-capacity designs that accept granular feedstone up to about 40 millimeters (1.57 inches). These developments tend to have greater applications outside the United States where plant sizes tend to be smaller and feedstone sources may be more variable (Oates, 1998b).

F.L. Smidth & Co. has developed a new type of burner for rotary kilns called Duoflex, which features a central duct for liquid and gaseous fuels placed inside an annular coal duct. The burner can fire all types of fuels and may be adapted to use secondary fuels. The burner also allows the option of changing primary air flow by adjusting the nozzle area (F.L. Smidth & Co., June 9, 1998, press release, accessed July 23, 1999, at URL http://www.flsmidth.com/news/news.htm).

As part of its Clean Coal Technology Program, the U.S. Department of Energy (DOE) has been funding a number of demonstration projects designed to evaluate the effectiveness of technologies that remove sulfur dioxide, nitrogen oxides, and other airborne pollutants. Several of these projects looked at lime-based technologies, such as the LIMB Extension and Coolside project, the Confined Zone Dispersion Flue Gas Desulfurization project, the SO_x-NO_x-Rox Box process, the Enhancing the Use of Coals by Gas Reburning and Sorbent Injection project, and the Integrated Dry NO_x/SO_2 Emissions Control System project. Individual project summaries can be downloaded from the DOE website (Los Alamos National

Laboratory, [no date], Clean coal technology compendium, accessed July 23, 1999, at URL http://www.1an1.gov/projects/cctc/projects/projects_fs.html).

Outlook

Lime has dozens of end uses in the chemical, industrial, and construction industries, but 70% is consumed in seven clearly defined markets—drinking water treatment, FGD, iron and steel, precipitated calcium carbonate, pulp and paper, ore concentration in the mining industry, and soil stabilization. The forces behind these markets include the health of the economy, imports, metals prices, weather conditions, and Federal funding levels.

Steelmaking remains the largest single end use for lime. As discussed earlier, efforts have been made to stem the influx of low-valued imports that have adversely affected domestic steel production. Unfortunately, when imports of a particular type of steel product are controlled, the result is invariably a shift to increased imports of other steel products not covered by the agreements or antidumping tariffs. With so much of the world's economy in recession, this pattern is likely to continue. Battling low-valued imports and its own excess capacity, the domestic steel industry may find it difficult to increase production, despite the strong economy. Consequently, lime sales to the steel industry face uncertainties in the short term caused by the import and capacity problems that beset the domestic steel industry and in the long term caused by steel industry changes in raw materials and flux usage, such as greater use of flux pellets and hot metal desulfurization.

The future of the FGD market, which rebounded in 1998, looks promising, and increased demand may result from the conversion of utilities in the Ohio River Valley to lime scrubbing from competing reagents, the utilities' decision to operate their scrubbers at higher recovery levels prompted by an increase in the sulfur content of their fuel or to overscrub to earn additional emission allowances, or expanding markets arising out of Phase II of the Clean Air Act Amendments of 1990 (CAAA), which takes effect January 1, 2000.

The sulfur dioxide removal processes with the longest proven track record are calcium-based scrubbers. To comply with Phase I of the CAAA, however, most utilities relied on fuel switching or purchased emission allowances. The DOE forecasts that scrubbers will be more cost competitive during Phase II of the CAAA because the cost of lime-based scrubbers has decreased from about $400 to $900 per ton of sulfur dioxide removed to about $300 per ton. Lime will compete primarily against limestone for this increased scrubber market. Lime scrubbers display favorable efficiencies and economics for small units. Regulations covering emissions from small municipal incinerators and waste to energy incinerators also favor the use of lime scrubbers. Quantifying the increased demand generated by Phase II and other emissions regulations is difficult, but the DOE estimates that about 23 gigawatts of coal-fired capacity will be retrofitted with scrubbers by 2010 (Los Alamos National Laboratory, [no date], Clean coal technology compendium, accessed July 23, 1999, at URL http://www.lanl. gov/projects/cctc/projects/projects_fs.html).

Lime sales for soil stabilization and use in asphalt exhibited healthy increases in 1998. The soil stabilization market is affected by the levels of funding for highway construction and private sector construction, the weather, and competition from products such as cement. The use of lime in asphalt paving is strongly affected by the levels of highway funding and by competition with cement and organic antistripping agents. The passage in 1998 of the Transportation Equity Act for the 21st Century is expected to significantly boost the stabilization and asphalt markets. This legislation has budgeted $167 billion over 6 years for highway construction; this is a 44% increase compared with the total for the previous 6 years. Healthy increases in lime sales for stabilization and asphalt are expected during this period.

Demand in lime's traditional pulp and paper market continued the downward trend of recent years and dropped to the lowest level since 1983. Despite the occasional upturn in demand resulting from increased pulp production, this market may continue to shrink because current environmental controls make it expeditious for pulp mills to regenerate as much lime from their carbonate sludge as possible, which lessens the need to purchase makeup lime.

The PCC market increased by 14% in 1998 and will probably continue to grow fueled by a healthy domestic economy and PCC's expansion into the groundwood paper and paper coating markets. Anticipated growth in the PCC market is expected to be particularly strong in the Southeastern United States.

In the ore concentration market, U.S. copper producers are under financial pressures because of low copper prices and excess world capacity. U.S. production of copper from concentrate is expected to decrease in 1999 and 2000. However, despite low gold prices, U.S. production remains strong with the United States remaining as the world's second largest producer.

In summary, sales for FGD, PCC, soil stabilization, and asphalt are expected to grow, but sales to the traditional pulp and paper market are expected to continue to decrease, the steel market is expected to be flat at best, and the ore concentration market will be adversely affected by decreasing copper production. On balance, the outlook for lime seems good. Lime sales have increased by about 3% per year in the past 3 years without the benefits expected from the new transportation legislation and the CAAA Phase II deadline. A growth rate of 3% to 5% in lime sales would not be unexpected, especially if the levels of steel imports are brought under control and domestic steel mills increase their output.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
SALIENT LIME STATISTICS 1/

(Thousand metric tons, unless otherwise specified) 2/

	1994	1995	1996	1997	1998
United States: 3/					
Number of plants	108 4/	106 4/	108 r/	106 r/	107
Sold or used by producers:					
High-calcium quicklime	NA	NA	NA	14,300	14,800
Dolomitic quicklime	NA	NA	NA	2,900	2,740
Total quicklime	14,800	15,800	16,800 r/	17,300 r/	17,500
High-calcium hydrated lime	NA	NA	NA	1,820 r/	1,980
Dolomitic hydrated lime	NA	NA	NA	352	383
Total hydrated lime	2,290 4/	2,390 4/	2,190 r/	2,170 r/	2,370
Dead-burned dolomite	300	308	300 5/	300 5/	300 5/
Grand total	17,400 4/	18,500 4/	19,100	19,700	20,100
Value 6/ thousands	$1,020,000	$1,100,000	$1,180,000 r/	$1,200,000 r/	$1,220,000
Average value per ton	$58.80	$59.20	$61.50 r/	$61.00 r/	$60.50
Lime sold	15,500 4/	16,400 4/	16,800	17,300	17,800
Lime used	1,910	2,180	2,430	2,400 r/	2,290
Exports 7/ 8/	74	72	50	80	56
Value thousands	$7,800	$8,490	$5,600	$9,550 r/	$9,110
Imports for consumption 7/ 8/	204	289	262	274	231
Value thousands	$13,100	$20,200	$19,400	$26,500	$22,700
Consumption, apparent 9/	17,500	18,700	19,400 r/	19,900 r/	20,300
World: Production	113,000 r/	115,000 r/	113,000 r/	115,000 r/	116,000 e/

e/ Estimated. r/ Revised. NA Not available.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ To convert metric tons to short tons, multiply metric tons by 1.10231.
3/ Excludes regenerated lime.
4/ Excludes Puerto Rico.
5/ Data rounded to one significant digit to protect company proprietary data.
6/ Selling value, f.o.b. plant, excluding cost of containers.
7/ Bureau of the Census.
8/ For 1994 through 1996, data include quicklime, slaked lime, and hydraulic lime; data for 1997 and 1998 also include calcined dolomite.
9/ Defined as sold or used plus imports minus exports.

TABLE 2
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

State	1997 Plants	1997 Hydrated (thousand metric tons)	1997 Quicklime (thousand metric tons)	1997 Total (thousand metric tons)	1997 Value (thousands)	1998 Plants	1998 Hydrated (thousand metric tons)	1998 Quicklime (thousand metric tons)	1998 Total (thousand metric tons)	1998 Value (thousands)
Alabama	5	131	1,700	1,830	$115,000	5	121	1,840	1,960	$119,000
Arizona, California, Nevada, Utah	13 r/	215	2,130	2,340	148,000	14	261	2,100	2,360	150,000
Colorado, Montana, Wyoming	10 r/	22	327	348	21,400	9	27	365	392	24,700
Idaho, Oregon, Washington	7	23	646	669	53,400	8	27	586	613	42,500
Illinois, Indiana, Missouri	8	350	3,380	3,730	217,000	8	356	3,600	3,960	226,000
Iowa, Nebraska, South Dakota	4	W	W	277	18,500	4	W	W	277	19,000
Kentucky, Tennessee, West Virginia	5	123	2,390	2,510	139,000	5	134	2,460	2,590	143,000
Michigan	8	--	802	802	42,600	8	--	761	761	40,300
Ohio	8	W	W	1,960	111,000	8	W	W	1,870	109,000
Pennsylvania	8	212	1,300	1,510	103,000	7	199	1,200	1,390	97,800
Texas	7	508	957	1,470	91,500	7	548	1,070	1,620	101,000
Virginia	5	125	693	818	49,300	5	137	723	859	51,700
Wisconsin	4	132	464	597	35,100	4	148	434	582	35,400
Other 3/	14	332	2,720	818 r/	55,400	15	407	2,640	902	59,900
Total	106	2,170	17,500	19,700	1,200,000 r/	107	2,370	17,800	20,100	1,220,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Excludes regenerated lime.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Includes Arkansas, Georgia, Louisiana, Massachusetts, Minnesota, North Dakota, Oklahoma, Puerto Rico, and data indicated by the symbol W.

TABLE 3
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY RANGE OF PRODUCTION 1/ 2/

Range of production	1997 Plants	1997 Quantity (thousand metric tons)	1997 Percent of total	1998 Plants	1998 Quantity (thousand metric tons)	1998 Percent of total
Less than 25,000 tons	22	258	1	21	269	1
25,000 to 100,000 tons	24	1,200	6	24	1,180	6
100,000 to 200,000 tons	21	2,700	14	24	3,200	16
200,000 to 300,000 tons	19	4,360	22	15	3,290	16
300,000 to 400,000 tons	6	1,850	9	8	2,410	12
400,000 to 600,000 tons	8	3,750	19	8	3,580	18
More than 600,000 tons	6	5,560	28	7	6,210	31
Total	106	19,700	100	107	20,100	100

1/ Excludes regenerated lime. Includes Puerto Rico.

2/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 4

LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

(Thousand metric tons and thousand dollars) 3/

Use	1997 Quantity 4/	1997 Value	1998 Quantity 4/	1998 Value
Chemical and industrial:				
Fertilizer (aglime and fertilizer)	24	1,790	33	2,480
Glass	141	9,130	105	6,050
Paper and pulp	976	60,400 r/	840	50,900
Precipitated calcium carbonate	868	51,800	989	58,600
Sugar refining	748	55,100	796	49,000
Other chemical and industrial	2,080	126,000	2,020	127,000
Total	4,840	305,000 r/	4,780	294,000
Metallurgical:				
Steel and iron:				
Basic oxygen furnaces	4,380	250,000 r/	4,420	253,000
Electric arc furnaces	1,330	82,300	1,450	89,500
Other steel and iron	348	21,300	206	13,000
Total	6,050	353,000	6,080	355,000
Nonferrous metals:				
Aluminum and bauxite	216	13,200	239	14,800
Other nonferrous metallurgy 5/	1,620	91,300 r/	1,530	87,300
Total nonferrous metals	1,840	104,000 r/	1,770	102,000
Total metallurgical	7,890	458,000 r/	7,850	457,000
Construction:				
Asphalt	237	18,900	319	24,800
Soil stabilization	1,060	66,000 r/	1,200	73,400
Other construction	332 r/	35,000 r/	382	38,300
Total	1,630	120,000 r/	1,900	137,000
Environmental:				
Flue gas sulfur removal:				
Utility power plants	2,590	135,000 r/	2,950	153,000
Incinerators	108	6,630	99	6,370
Other	56	3,560	56	3,540
Total	2,750	145,000 r/	3,110	163,000
Sludge treatment:				
Sewage	335	23,000	325	22,400
Other (industrial, hazardous, etc.)	96	6,310	178	11,500
Total	431 r/	29,300	503	33,800
Water treatment:				
Acid mine drainage	172	11,500	135	9,370
Drinking water	895	56,600	883	55,500
Wastewater	485	31,100 r/	388	25,600
Total	1,550	99,200 r/	1,410	90,500
Other environmental	309	20,100	317	20,200
Total	5,050 r/	294,000 r/	5,340	308,000
Refractories (dead-burned dolomite) 6/	300	NA r/	300	NA
Grand total	19,700	1,200,000 r/	20,100	1,220,000

r/ Revised. NA Not available.

1/ Excludes regenerated lime. Includes Puerto Rico.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ To convert metric tons to short tons, multiply metric tons by 1.10231.

4/ Quantity includes lime sold and used, where "used" denotes lime produced for internal company use for copper ore concentration, magnesia, paper and pulp, precipitated calcium carbonate, basic oxygen furnaces, mason's lime, and refractories.

5/ Includes ore concentration (copper, gold, etc.), magnesium, and other.

6/ Data rounded to one significant digit to protect company proprietary data.

TABLE 5
HYDRATED LIME SOLD OR USED IN THE UNITED STATES, BY END USE 1/ 2/

(Thousand metric tons and thousand dollars) 3/

Use	1997 Quantity 4/	1997 Value	1998 Quantity 4/	1998 Value
Chemical and industrial	384	30,800	425	33,800
Construction:				
Asphalt paving	233	18,700	308	24,200
Building uses	310	33,400	352	36,200
Soil stabilization	433	29,400	486	31,600
Other construction	18	1,290	25	1,840
Total	995	82,800	1,170	93,900
Environmental:				
Flue gas treatment (FGT):				
Incinerators	10	727	13	996
Industrial boilers and other FGT	22	1,520	31	2,100
Utility powerplants	19	1,430	41	2,960
Total	51	3,680	85	6,060
Sludge treatment:				
Sewage	148	11,700	150	11,900
Other sludge treatment	27	2,330	11	1,080
Total	175	14,000	161	13,000
Water treatment:				
Acid mine drainage	117	7,940	86	6,170
Drinking water	247	19,300	236	18,000
Wastewater	111	8,280	111	8,390
Total	475	35,600	433	32,600
Other environmental	52	4,200	41	3,260
Metallurgy	40	3,180	48	3,980
Grand total	2,170	174,000	2,370	187,000

1/ Excludes regenerated lime. Includes Puerto Rico.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ To convert metric tons to short tons, multiply metric tons by 1.10231.
4/ Quantity includes hydrated lime sold or used, where "used" denotes lime produced for internal company use in building, chemical and industrial, and metallurgical sectors.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF LIME, BY TYPE 1/

Type	1997 Quantity 2/ (metric tons)	1997 Value 3/	1998 Quantity 2/ (metric tons)	1998 Value 3/
Quicklime:				
Canada	186,000	16,600,000	144,000	12,300,000
Mexico	--	--	40	2,870
Other 4/	76	107,000	54	71,200
Total	186,000	16,700,000	144,000	12,400,000
Calcined dolomite:				
Canada	33,600	4,600,000	32,500	4,370,000
Mexico	314	51,100	112	17,000
Other 5/	836	120,000	11,200	1,510,000
Total	34,800	4,770,000	43,800	5,900,000
Slaked lime (hydrate):				
Canada	37,000	3,280,000	27,700	2,570,000
Mexico	7,380	951,000	9,400	1,260,000
Other 6/	3	3,370	48	130,000
Total	44,400	4,240,000	37,100	3,960,000
Hydraulic lime:				
Canada	1,240	134,000	136	8,850
Mexico	7,340	633,000	6,380	496,000
Total	8,580	767,000	6,520	505,000
Grand total	274,000	26,500,000	231,000	22,700,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ To convert metric tons to short tons, multiply metric tons by 1.10231.
3/ Declared c.i.f. valuation.
4/ Includes China, Germany, Japan, Thailand, and the United Kingdom..
5/ Includes Austria, China, Germany, Hong Kong, the Republic of Korea, and Norway.
6/ Includes Germany, Italy, Japan, Taiwan, and Thailand.

TABLE 7
U.S. EXPORTS FOR CONSUMPTION OF LIME, BY TYPE 1/

Type	1997 Quantity 2/ (metric tons)	1997 Value 3/	1998 Quantity 2/ (metric tons)	1998 Value 3/
Calcined dolomite:				
Brazil	--	--	113	28,200
Canada	3,310	698,000	1,990	407,000
Chile	174	52,200	--	--
Japan	--	--	568	149,000
Mexico	13,000	1,760,000	7,080	1,200,000
Netherlands	146	36,500	--	--
Taiwan	--	--	656	154,000
Trinidad and Tobago	2,780	356,000	--	--
United Kingdom	--	--	517	86,800
Venezuela	222	119,000	1,310	327,000
Total	19,700	3,020,000	12,200	2,350,000
Hydraulic lime:				
Bahamas, The	103	35,500	64	11,700
Chile	--	--	956	185,000
Canada	2,710	439,000	5,130	835,000
Dominican Republic	134	24,100	--	--
Mexico	50	14,000	--	--
New Zealand	16	5,600	116	80,200
Other 4/	79	58,800	79	662,000
Total	3,100	577,000	6,350	1,770,000
Quicklime:				
Canada	38,900	3,440,000	22,900	2,250,000
Costa Rica	327	45,900	322	61,000
Guyana	402	33,100	1,920	506,000
Indonesia	2,000	294,000	--	--
Jamaica	1,470	128,000	--	--
Mexico	3,280	542,000	5,160	921,000
Suriname	5,020	569,000	922	106,000
Other 5/	244	78,400	137	59,000
Total	51,600	5,130,000	31,400	3,900,000
Slaked lime (hydrate):				
Canada	5,180	749,000	5,380	845,000
Mexico	56	9,950	62	19,500
Philippines	118	34,800	658	161,000
South Africa	67	21,300	28	8,460
Other 6/	21	3,490	139	53,400
Total	5,440	818,000	6,260	1,090,000
Grand total	79,800	9,550,000	56,200	9,110,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ To convert metric tons to short tons, multiply metric tons by 1.10231.
3/ Declared "Free alongside ship" (f.a.s.) valuation.
4/ Includes Antigua, Australia, Barbados, Ecuador, Finland, Haiti, Singapore, Switzerland, Taiwan, and Venezuela.
5/ Includes The Bahamas, Belgium, Guadeloupe, Haiti, India, the Philippines, Singapore, the United Kingdom, and Venezuela.
6/ Includes The Bahamas, the Republic of Korea, Trinidad and Tobago, and the United Kingdom.

TABLE 8
QUICKLIME AND HYDRATED LIME, INCLUDING DEAD-BURNED DOLOMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1994	1995	1996	1997	1998 e/
Australia e/	1,500	1,500	1,500	1,500	1,500
Austria	1,850	1,908	1,990	1,900 e/	1,900
Belgium e/	1,750	1,800	1,800	1,750	1,750
Brazil e/	5,700	5,700	5,700	5,700	5,700
Bulgaria	665	952	1,000 e/	1,200 e/	1,100
Canada	2,390 e/	2,398	2,402	2,477 r/	2,514 p/
China e/	19,500	20,000	20,000	20,500	21,000
Colombia e/	1,300	1,300	1,300	1,300	1,300
Czech Republic	1,206	1,186	1,176	1,200 e/	1,200
France	3,015	2,940	2,714	2,800 e/	2,800
Germany	8,511	8,000 e/	7,570 r/	7,600 r/ e/	7,600
Italy e/ 4/	3,500	3,500	3,500	3,500	3,500
Japan (quicklime only)	7,712	7,871	7,744	8,104 r/	8,100
Mexico e/	6,500	6,580 5/	6,600	6,600	6,600
Poland	2,516	2,526	2,363 r/	2,500 e/	2,500
Romania	1,621	1,763	1,712	1,750 e/	1,700
Russia 6/	9,000 e/	9,263	7,822	7,626	7,000
South Africa (sales)	1,597	1,743	1,518 r/	1,514 r/	1,500
United Kingdom e/	2,500	2,500	2,500	2,500	2,500
United States, including Puerto Rico (sold or used by producers)	17,400	18,500	19,200 r/	19,700	20,100 5/
Other e/	13,300 r/	12,600 r/	13,000 r/	12,900 r/	13,800
Total	113,000 r/	115,000 r/	113,000 r/	115,000 r/	116,000

e/ Estimated. p/ Preliminary. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through June 3, 1999.
3/ Lime is produced in many other countries besides those included in the total. Argentina, Iraq, Pakistan, and Syria are among the more important countries for which official data are not available.
4/ Includes hydraulic lime.
5/ Reported figure.
6/ Data are the total industrial and construction production as reported by Russia.